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Behavioral Responses to Road Pricing

Empirical Results from a Survey of Dutch Car Owners

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For the evaluation and design of transport pricing strategies, it is important to have insight into the behavioral responses induced by transport pricing. Relevant dimensions of behavior include trip suppression, mode choice, and departure time choice. The results from a questionnaire among Dutch car owners are presented. The behavioral responses to two Dutch policy-relevant road pricing measures were analyzed. Depending on the type of measure, reductions of 6% to 15% were found in the number of car trips, which is in line with previous findings. A flat kilometer charge affects social trips considerably more than commuting trips. Respondents do appear to adjust commuting trips when a peak hour charge is implemented. Nonmotorized travel and trip suppression are the most popular alternatives for noncommuting trips. Departure time changes become attractive for all purposes when the proposed measure varies over time. Important explanatory variables for these effectiveness levels include the type of measure, income, and the possibility for commuters to work at home.

People's responses to transport pricing are not straightforward. Price increases may induce modelers not to travel anymore or to change their modal use or departure time, depending on the type of measure. A wide variety of transport pricing measures exists, having different consequences for travel behavior. Price measures are seen as one of the major tools for policy makers to influence transport development. The design of measures will generally depend on the objectives set by the government. It is therefore important for authorities to have clear insight into the responses induced by transport pricing. This response will depend, to a considerable extent, on the exact design of the pricing scheme (e.g., a yearly tax on car ownership can be expected to affect kilometrage of a given vehicle relatively weakly, compared with a kilometer charge). Equally important, however, is the price sensitivity of transport users for the various relevant types of behavior that together define transport behavior. Such dimensions of behavior may include, for instance, trip suppression, mode choice, and route choice. People have various possibilities to change transport behavior and can be expected to react differently to different pricing schemes.

This paper presents the empirical results from a survey among Dutch car owners toward the behavioral effects of various policy-relevant, road pricing measures. Two types of measures have been evaluated by the respondents. The short-term behavioral responses will be analyzed for sensitivity and type of change for three trip purposes. Furthermore, the aim is to find explanatory variables for the self-reported level of effectiveness (expressed as the share of trips that will be changed).

This paper is organized as follows. The following section gives an overview of previous literature results. The next section explains the structure of the questionnaire and the type of pricing measures that have been evaluated by the respondents. The next section presents the effectiveness outcomes, in terms of car trips that will be replaced (and how these trips will be changed). A statistical analysis is conducted in the following section, which identifies important explanatory variables for the level of effectiveness of each type of measure. The final section presents conclusions.

ROAD TRANSPORT PRICING AND BEHAVIORAL RESPONSES

Transport users will respond differently to various pricing policies. The possible behavioral responses to pricing include, among others, trip suppression (travel frequency choice), departure time choice (and rescheduling of daily activities), route choice, and mode choice. Depending on the desired aim, policy makers decide to make use of a particular price instrument that is likely to steer travel behavior in a more desired direction. However, the eventual effect of a price change depends on various factors, which makes the predictability of the effects from a certain measure rather difficult. Factors affecting price sensitivity include (*1*)

- Type of price change. The types of pricing measures can have different effects on travel behavior.
- Type of trip and modeler. Commute trips tend to be less elastic than shopping or recreational trips.
- Quality and price of alternative routes, modes, and destinations. Price sensitivity tends to increase if alternative routes, modes, and destinations are of good quality and affordable (for example, road users tend to be more price sensitive if there is a parallel untolled roadway).
- Time period. Transportation elasticities tend to increase over time as consumers have more opportunities to take prices into effect when making long-term decisions (*2*).
- Large and cumulative price changes. Extra care should be used when calculating the impacts of large price changes or when summing the effects of multiple changes, because each subsequent change affects a different base.

A substantial body of economic literature analyzes the effects of transport pricing measures on particular types of behavior. Elasticities, for example, have been widely studied. Most of these studies have looked at the effect of fuel prices on car stock, fuel consumption

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and car use. Goodwin (*3*), for instance, finds a long-run price elasticity of kilometers driven with respect to fuel price of –0.33; in the short-run this is –0.16. Despite the fact that road pricing is not widely implemented, practical experiences provide valuable results on effectiveness. Singapore, for instance, has experience since 1975, and results show that traffic is quite sensitive to the road pricing system even though the charges are relatively low (*4*). The study suggests that time-of-day charging may lead to considerable departure time and mode choice effects, but much depends on local situations (e.g., public transport availability).

This study focuses on one particular type of price measure, which is policy relevant in the Netherlands—the implementation of a kilometer charge and simultaneous abolition of existing fixed car taxation (this measure is often called variabilization). Current fixed car taxation has two main components in the Netherlands: a tax on car ownership (to be paid yearly, the MRB) and a tax to be paid when purchasing a new car (the BPM). A brief discussion of some previous literature results on this type of measure follows.

One of the first studies of the mobility effects of variabilization was conducted by MuConsult in 1998 (*5*). A simulation model was used to study the effects of different kilometer charges with the restriction that the revenues for the government remain constant (fixed car taxation was lowered or abolished). The study shows that, depending on the level of the charge, implementation may lead to a considerable reduction in total kilometers driven. A kilometer charge of 7 (euro) cents, for instance, leads to a total reduction of 19% of vehicle kilometers driven. Business travel is least affected (7%), whereas social travel (23%) and commuting (19%) are most sensitive. Most of these car kilometers are replaced by bicycle use and carpooling. Effects are less strong when the charge is lower. A charge of 3 (euro) cents is estimated to reduce commuting by 5% and social travel by 8%. A remarkable prediction of this study is the decrease in car ownership (for all scenarios considered). Apparently, the effect of the increase in the variable charge dominates the effect of lower ownership costs.

A stated-preference survey among car owners as well as non-car owners reported in MuConsult (*6*) also analyzed the behavioral responses to different types of kilometer charging with abolition of fixed taxes, either of MRB only, or of both the MRB and the BPM. The charges were differentiated according to fuel type. The MRB-only scenario included a charge of 2.4 (euro) cents per kilometer for petrol-using cars (and slightly higher charges for cars running on diesel and gas). The MRB+BPM scenario contained a charge of 4.9 (euro) cents with equal levels for other fuel types. In contrast to the previous study, this study predicts an increase in car ownership levels for all alternatives considered. The predicted car stock shows a stronger growth under the MRB-only scenario than in the MRB+BPM scenario (2.8% versus 1.2%). The higher charges in this latter scenario induce relatively more car owners (4.6% versus 1.3%) to sell their car. The results in terms of vehicle kilometers indicate a small reduction for the MRB-only scenario of about 0.9% and a somewhat larger effect of 3.4% for the other scenario. These effects include a decrease in kilometers by car owners and an increase of kilometers driven by respondents who intend to purchase a new car (estimated around 2% for both scenarios). Especially social, shopping, and recreational trips will be adjusted, whereas business travel and kilometers driven for school or educational purposes remain almost unchanged. Commuting trips will be changed (about 30% of the respondents intended to reduce their number of kilometers driven for this purpose) but less often than the social and shopping trips.

Recently, initiated by a request from the Dutch Minister to search for a new, widely approved, pricing regime, the effects of various road pricing alternatives have been estimated with the national network model for the Netherlands (Landelijk Model Systeem,LMS) (*7*). Among the 10 alternatives that have been evaluated were four variabilization measures. When all fixed taxes are replaced by a kilometer charge (with budget neutrality for the government), the model predicts a decrease in car use (in terms of kilometers) of 11% (compared with the reference situation in 2020). The average charge per kilometer causing these effects was about 5.7 (euro) cents and depended on fuel type and weight of the car. The growth in congestion will be reduced by 40% (in terms of vehicle hours lost). People will change mode (use of train, bus/metro, and nonmotorized transport increases by 6%), and especially social travel (29%) and to a lesser extent commuting (9%) will be reduced.

Another considered alternative included variabilization of all car ownership taxes (MRB) plus only one-quarter of the car purchase taxes (BPM). The average kilometer charge is consequently lower [3.4 (euro) cents] than the previous measure, but an additional charge of 0.11(euro) cents was levied on locations and times with severe congestion. The LMS model outcomes suggest that congestion will be reduced by about 45%. Trip distances will decrease. This effect is small for commuting trips but larger for social trips. Business travel (6%) and freight traffic (1%) are predicted to increase, but total travel demand will decrease (by 10%) due to considerably less commuting (16%) and social kilometers (25%).

DATA COLLECTION AND SURVEY DESCRIPTION

Data Collection

The data for this study were obtained from an (interactive) Internet survey among Dutch car owners. The total sample consists of 562 respondents. These respondents were presented with two road pricing measures and were asked if and how they expect to change their behavior when facing these measures. The focus here is on the short-term responses. The data were collected during 3 weeks in February 2005.

Survey

Two pricing measures will be considered in this paper, each in multiple alternatives. Table 1 shows these six alternatives for both measures. The alternatives were divided randomly among the respondents, and each respondent evaluated one alternative of each measure. This means that at least 88 observations were obtained for each alternative of both measures.

All descriptions of the measures, as shown to the respondents, consisted of two major components: (*a*) an explanation of both the structure and the level of the charge and the allocation of the revenues and (*b*) an estimation, provided to each respondent individually, of the financial consequences of the implementation of the proposed measure with unadapted behavior (on the basis of self-reported travel behavior and car ownership). This estimation depends on the charge level (costs) and on the type of revenue use (benefits). Information on the annual number of kilometers driven and time of driving (Measure 2) is the input for the cost estimation. The financial benefits shown to the respondent depend on the type of revenue use. Because it was impossible to give respondents a personal estimation of the financial benefits involved with a recycling via lower-income taxation, the savings for those measures were presented only when

TABLE 1 Description of the Road Pricing Measures Presented to Respondents

Measure	Alternatives
1: flat kilometer charge with different revenue allocations	A: 3 € cent, revenues used to abolish car ownership taxes (MRB) B: 6 € cent, revenues used to abolish existing car taxation (purchase (BPM) and ownership (MRB) C: 12 € cent, revenues used to abolish existing car taxation and construct new roads D: 3 € cent, revenues used to lower income taxes E: 6 € cent, revenues used to lower income taxes F: 12 € cent, revenues used to lower income taxes
2: peak and off-peak kilometer charge and different revenue allocations	A: 2 € cent outside peak times and 6 € cent in peak on working days (7.00–9.00 and 17.00–19.00), abolition of car ownership taxes (MRB) B: 4 € cent outside peak times and 12 € cent in peak on working days (7.00–9.00 and 17.00–19.00), abolition of existing car taxation (BPM and MRB) C: 8 € cent outside peak times and 24 € cent in peak on working days (7.00–9.00 and 17.00–19.00), abolition of existing car taxation and new roads D: 2 € cent outside peak times and 6 € cent in peak on working days (7.00–9.00 and 17.00–19.00), revenues used to lower income taxes E: 4 € cent outside peak times and 12 € cent in peak on working days (7.00–9.00 and 17.00–19.00), revenues to lower income taxes F: 8 € cent outside peak times and 24 € cent in peak on working days (7.00–9.00 and 17.00–19.00), revenues used to lower income taxes

€ = euro

existing car taxes are abolished. The benefits from paying less car taxation depend on the type of car the respondent owns (i.e., fuel type and weight). Averages were estimated for nine categories (a combination of three fuel types and three weight categories) for an abolition of MRB only and an abolition of all existing car taxation.

Some practical issues also were explained, which were meant to prevent various practical considerations from affecting the responses. In particular, the respondents were to assume that the privacy of car users is guaranteed, electronic equipment registers the toll, and the driver can choose freely the payment method (e.g., credit card, bank transfer, etc.).

The survey started with some general questions asking for important background variables of the respondent. These variables may help explain the differences in self-reported effectiveness levels. The variables included in the statistical analyses are explained in more detail in Table 2, showing the profile of the sample.

TABLE 2 Explanation and Population Share of Explanatory (Dummy) Variables in Original Data Set

Variable	Type	Levels
Gender	Dummy	Male (61.2%), female (38.8%)
Age	Continuous	
Income (gross yearly)	Dummies	Inc1: less than €28,500 (21.4%), Inc2: €28,500–45,000 (31.5%), Inc3: €45,000–68,000 (28.5%), Inc4: more than €68,000 (15.7%), Inc5: do not know or won't say (3.0%)
Weekly number of times in congestion	Continuous	
Employed	Dummy	Employed (82.7%); not employed (17.3%)
Trip purpose (effect of measure on type of car trip) (for $N = 1370$)	Dummies	Dummy commuting (29%), dummy visiting (33%), dummy other (38%)
Type of measure (charge)	Dummies	Dummy charge 3 € cent (measure 1) Dummy charge 6 € cent (measure 1) Dummy charge 12 € cent (measure 1) Dummy peak charge 6 € cent (measure 2) Dummy peak charge 12 € cent (measure 2) Dummy peak charge 24 € cent (measure 2)
Type of measure (revenue use)	Dummy	Dummy road taxes [revenues are used to lower existing road taxes (1A, 1B, 2A, 2B) and construct new roads (1C and 2C)] Dummy income taxes (revenues are used to lower income taxes, measures 1D to 1F and 2D to 2F)
Possibility to work at home (available for employed people making a commuting trip by car at least once a week)	Dummies	Working home1: possible to work at home (26%), Working home2: not possible (42.2%), Working home3: unknown (31.8%)
Yearly number of kilometers driven	Continuous	
Compensation of costs by employer (available for employed people making a commuting trip by car at least once a week)	Dummies	Comp1: none (11.4%), comp2: partly (32.2%), comp3: completely (19.9%), comp4: have no commuting costs (4.8%), comp5: unknown (31.8%)
Children in household	Dummy	Yes (one or more) (45.7%); No (54.3%)

$N = 562$

Statistics on the profile of Dutch car owners are unfortunately not available. A review of some statistics gives a first impression on representativeness. The educational level of the sample appears relatively high. About 29% of the Dutch car owners have a bachelor's or master's degree (this is based on the authors' calculations of data for 2003). The share is considerably higher in this survey (40%). Younger people appear to be overrepresented in the survey. About 30% of the car owners in the Netherlands are older than 55, while this share is only 16% in this survey.

The question of whether respondents have the possibility of working at home may have an impact on the effectiveness of a road pricing measure, and it has been included in the analysis. About 26% of the respondents have the possibility of working often or always at home. Respondents who do not make commuting kilometers by car or do not have a job have not answered this question (about 32% of the sample). The respondents were also asked if they receive compensation for their commuting costs from their employer. Most car owners are at least partly compensated. A small group incurs no commuting costs. This may be people having their work at home, but it also may include respondents who misinterpreted the question and in fact are completely compensated by their employer (these persons indicated that they do commute partly or wholly by car). The respondent was not informed about how employers will compensate for modeling costs after pricing is implemented.

After a concise description of each measure, the respondents were asked whether they would change the number of car trips for three different trip purposes (only when the respondent indicates that he or she actually makes this type of trip):

- Commuting trips (made at least sometimes by 70.8% of the respondents),
- Trips to visit people (made at least sometimes by 80.1% of the respondents), and
- Other types of trips (e.g., shopping, sports activities, made at least sometimes by 92.9% of the respondents).

If respondents indicated that they indeed expect to adjust their travel behavior, they were next asked to indicate the share of trips that will be changed and also how the trips will be changed. It was possible for people to indicate that they would make more car trips. In that case, they were asked only how many extra trips they would make. Depending on the type of measure and trip, various possibilities were presented:

- Public transport,
- Nonmotorized travel (walking, bicycle),
- Motorized private transport (motorbike, motor),
- Carpool (only asked for commuting trips),
- Work at home (only asked for commuting trips),
- Travel at other times (only when measure is time dependent), and
- Give up the trip.

To analyze the behavioral responses to the proposed pricing measure in a quantitative way, the respondents were asked to indicate for each purpose how many trips they make in a normal week. Because some types of trips are made only once a week, the respondents were asked to indicate how many trips they will change in a period of 4 weeks (presenting their total number of trips made for each purpose). Hence, a respondent indicating that he or she makes five commuting trips a week could change 20 trips at most. Next it was asked how these trips will be changed. Respondents could not continue with the survey when the number of trips to be changed was unequal to the sum of numbers allocated to various alternatives.

EFFECTIVENESS OF DIFFERENT PRICING REGIMES

The aim now is to analyze the behavioral responses to the various pricing measures. This section focuses on the sensitivity and type of effect of the short-term responses to two different measures for three different trip purposes [i.e., commuting, social travel (visits), and other (e.g., shopping)]. With survey information on the behavioral responses (number of trips that an individual will adjust and how these will be adjusted) and an individual estimation of the yearly number of kilometers driven for each trip purpose, it is also possible to express changes in terms of kilometers.

Measure 1. Flat Kilometer Charge [3, 6, and 12 (euro) cents] and Different Types of Revenue Use

The percentage of respondents who indicated they would adjust their car trips when Measure 1 became reality were 11% for commuting, 26% for visits, and 24% for other trip purposes. After these adjustments by numbers of trips made and by the length of these trips were weighed, these figures can be transformed into changes in numbers of trips and vehicle kilometers. Table 3 shows the aggregated outcomes for all alternatives of Measure 1 together.

The numbers vary considerably over the various trip purposes. The proposed kilometer charge is relatively most effective for trips made to visit people, and least so for commuting trips. This may be explained by the fact that a trip suppression is no alternative for commuting trips: only 0.5% of trips to be adjusted would not be made anymore. For other reasons, people consider the alternative of not making the trip more often. Popular alternatives (for all purposes) for car trips include nonmotorized transport and public transport. Cycling and walking in particular are alternatives for visits and other trips; apparently these trips are often of short distance. The effectiveness as shown by adjusted number of kilometers is less than for numbers of trips, probably because people driving relatively fewer kilometers more easily adjust their behavior.

It is also interesting to consider the relative effectiveness of the various alternatives of Measure 1. A kilometer charge of 12 (euro) cents tends to have more effect than a similar measure with lower charges. The lower panel of Table 3 shows the impact of each alternative for the various trip purposes. Some results are different than expected: a measure with a higher charge is not always more effective. For instance, Measure 1D [with a charge of 3 (euro) cents] appears slightly more effective than Measure 1E [6 (euro) cents] for particular trip purposes. Measure 1F induces the strongest trip changes. Alternatives A, B, and C are variabilization measures, and these appear to be less effective than the measures in which revenues are used to lower income taxes. The perceived higher costs for each individual involved with the latter measures, stemming from the inability to predict the reduction in income tax, may form an explanation for this. If so, the bias results from the design of the questionnaire. None of the 96 respondents who evaluated Measure 1A (with the low toll) indicated that he or she would change commuting trips.

TABLE 3 Aggregated Outcomes of Behavioral Responses to Measure 1 (Flat Kilometer Charge) Including Effectiveness of Each Alternative

	Commuting	Visits	Other
Total Number of Trips (driven in 4 weeks)	6800	3620	7780
Number of trips adjusted	400 (5.9%)	513 (14.2%)	846 (10.9%)
Public transport	31.8%	17.8%	13.3%
Nonmotorized travel	32.2%	44.6%	64.9%
Motorized	9.5%	8.9%	1.8%
Carpool	19.5%	Not relevant	Not relevant
Working at home	6.5%	Not relevant	Not relevant
Not making trip	0.5%	28.6%	19.9%

	Number of Respondents	% of Total Trips Adjusted		
		Commuting	Visits	Other
Measure 1A	96	0	9.5	13.6
Measure 1B	94	5.0	9.4	9.5
Measure 1C	88	11.3	20.3	17.6
Measure 1D	101	25.0	15.0	21.2
Measure 1E	91	19.7	20.5	16.7
Measure 1F	92	39.0	25.3	21.5
Kilometers adjusted (in % of total)		3.9%	11.6%	9.2%

Measure 2. Peak–Off-Peak Kilometer Charge with Different Revenue Use

The second measure is a kilometer charge differentiated crudely according to time (peak and off-peak only), with different revenue use allocations. Compared with the previous measure, this measure is, in terms of total number of adjusted trips (for all purposes), more effective (14.1% versus 9.7%). This measure has relatively more impact on commuting trips. The number of commuting trips changed is 1,004—14.8% of the total trips made for commuting reasons, considerably more than 5.9%. Almost half of the trips that will be adjusted will be replaced by trips made off-peak (see Table 4). Nonmotorized travel is also an attractive alternative, but again only for noncommuting purposes. The motor or motorbike is not a serious alternative for the respondents, and the same holds for carpooling.

The pattern shown in the lower part of Table 4 is somewhat different from what could be expected. This measure combines different charge levels with different types of revenue use. Alternatives C and F have the highest charges, considerably higher than A and D. The estimated benefits of revenue use for Alternatives A to C have been presented to the respondents, but this has not been done for the alternatives in which revenues are used to lower income taxes (D to F). Since higher charges tend to have more effect, Alternatives C and F may be expected to have more effect than the other alternatives, and B and E again more than A and D. This is not entirely true. Measure 2B, for instance, is considerably less effective than Measure 2A for all purposes. A similar pattern is found for Measure 2E, compared with 2D. Most remarkable is that the alternatives with the lowest charge levels (A and D) are even more effective than Alternatives C and F for certain purposes. The findings for the impact of revenue use (abolition of car taxation versus income tax reductions) are, for most trip purposes, equal to the results for Measure 1: variabilization is said to be less effective. Only the outcomes for Measures 2C (visits) and 2A (other purposes) are different in this context, and revenues hypothesized to reduce car taxation dominate income tax compensation in terms of effectiveness. The impact of the type of measure (distinction between revenue use and charge level) will be analyzed in a more detailed way by conducting a statistical analysis in the next section.

When the effects of the measure for trip purposes are examined, it appears that Measure 2C has more effect on social visiting trips than on trips for other purposes. The reverse holds for the same purpose for Measure 2F. Measure 2D tends to be less effective for other trips, while Measure 2A appears most effective for this type of trip. There appears to be not much difference between trip purposes for the other measures.

STATISTICAL ANALYSIS

The aim of this section is to find and interpret factors that have an impact on the level of effectiveness. Socioeconomic characteristics of the respondents, type of measure evaluated, and other information available (answers to other questions) will be linked to the trip changes reported by the respondents. The methodology is explained first.

Methodology

The methodology to be applied is motivated by the structure of the data. The aim is to explain the level of self-reported effectiveness for the various measures. The dependent variable is the fraction of the total trips made during 4 weeks that will be adjusted as indicated by the respondents, that is, a number between zero (no change) and one (all car trips will be adjusted). This information is available for

TABLE 4 Aggregated Outcomes of Behavioral Responses to Measure 2 (Peak and Off-Peak Kilometer Charge) Including Effectiveness of Each Alternative

	Commuting	Visits	Other
Total Number of Trips (driven in 4 weeks)	6800	3620	7780
Number of trips adjusted	1004 (14.8%)	529 (14.6%)	1028 (13.2%)
Public transport	17.6%	13.6%	14.1%
Nonmotorized travel	12.7%	28%	28.9%
Motorized	8.8%	1.7%	1.5%
Carpool	4.5%	Not relevant	Not relevant
Travel at other times	47.7%	47.8%	47.3%
Working at home	7.9%	Not relevant	Not relevant
Not making trip	0.6%	8.9%	8.3%

	Number of Respondents	% of Total Trips Adjusted		
		Commuting	Visits	Other
Measure 2A	96	16.0	14.2	21.6
Measure 2B	91	13.8	10.0	12.1
Measure 2C	97	15.8	25.9	13.1
Measure 2D	96	19.0	18.9	14.4
Measure 2E	94	13.9	14.4	15.7
Measure 2F	88	21.3	16.6	23.2
Kilometers adjusted (in % of total)		14.6%	13.2%	11.2%

all three distinguished trip purposes. Only those respondents who actually make more than one trip per week for a particular type of trip purpose have been included in the data set. This reduces the data set to 398 respondents who make commuting trips, 450 who make social trips (visits), and 522 respondents who use the car to go shopping or to participate in sports.

The dependent variable is not of an ordinary type. Because most of the people indicate no change in behavior, the effectiveness variable is often a zero. This has consequences for the applied methodology. To increase the number of observations, it was decided to pool the three (for each purpose) observations but to keep the data for both measures separated. This pooled data set contains 1,370 observations. This increases the sample size for each measure, while it is still possible to correct for different trip purposes.

The structure of the dependent variable is such that a standard type of regression analysis (assuming a normal distribution of the error term) is not applicable, due to the large number of zero-value observations. Censored regression models, in which the dependent variable is observed in only some of the ranges, is more appropriate. Tobin (*8*) analyzed this problem and formulated a regression model that was later called the Tobit model. This model is defined as follows when censoring takes places at zero, as in this case (*9*, p. 151):

$$y_i = \begin{cases} \beta' x_i + u_i & \text{if } \beta' x_i + u_i > 0 \\ 0 & \text{otherwise} \end{cases}$$

where

y_i = the effect of the measure (the fraction of trips changed) as reported by individual *i;*
x_i = a set of explanatory variables;
β' = a vector of coefficients to be estimated; and
u_i = residuals that are independently and normally distributed, with mean zero and a common variance.

This implies that y_i is considered as the observed realization of an underlying latent variable that describes the intention of a respondent to change behavior. When this intention is positive, the observed variable is equated to the latent variable. When the latent variable is zero or smaller than zero, the measurement variable equals zero, thus $y_i = 0$. An upper limit of 1 was imposed to the dependent variable, since all values of the dependent variable are between zero and one. The computer program Limdep was used to obtain the maximum likelihood estimates of the parameter values for the explanatory variables.

Various specifications of the model for all measures (by including variables that may be expected to have some explanatory power) have been tried, and the preferred specifications of the Tobit analyses are presented. The results presented are the marginal effects on the observed effectiveness. These coefficients can be interpreted more easily than the standard output of the maximum likelihood estimates which relate to the latent variable. The estimations for both measures have been done with the same explanatory variables (except for the "type of measure" variable) to maximize comparability between the models.

Measure 1. Flat Kilometer Charge [3, 6, and 12 (euro) cents] and Different Types of Revenue Use

Table 5 presents the estimation results for Measure 1. The data set contains 1,081 zero observations, leaving 289 observations of changed behavior. The first column of Table 5 presents all explanatory variables that have been included in the estimation. It appears that the type of measure (split into charge level and type of revenue use) has a significant impact on the individual effectiveness scores. As expected, the measures with lower charge levels [3 and 6 (euro) cents compared with 12 (euro) cents] are in general less effective. Variabilization appears less effective than use of revenues to lower income taxes. This can be explained by the fact that with the latter types of

TABLE 5 Estimation Results (Marginal Effects) of Tobit Analysis with the Effectiveness of Measure 1 as Dependent Variable

Variable	Tobit *y* Measure 1	Sign.
Constant	−.048 (.315)	*
Yearly driven number of kilometers	−.374E-06 (.31E-06)	
Age	−.472E-03 (.45E-03)	
Weekly number of times in congestion	−.760E-03 (.45E-03)	
Income (dummy inc1 = base)		
Incunk (do not know or won't say)	−.119 (.048)	**
Inc2 (€2 8.500–45.000)	.016 (.013)	
Inc3 (€45.000–68.000)	.003 (.014)	
Inc4 (>68.000)	−.047 (.019)	**
Type of measure (dummy charge 12 = base)		
Dummy charge 3 €cent	−.052 (.012)	***
Dummy charge 6 €cent	−.033 (.012)	***
Type of measure (dummy road taxes = base)		
Dummy income taxes	.040 (.010)	***
Trip purpose (dummy other = base)		
Dummy commuting	−.062 (.014)	***
Dummy visiting	.017 (.012)	
Employed		
Dummy yes	−.023 (.012)	
Possibility to work at home (dummy working home2 and working home3 = base)		
Working home1 (possible)	.027 (.013)	**
Compensation for commuting costs (dummy comp4 = base)		
Comp1 (no costs paid by employer)	.026 (.019)	
Comp2 (costs partly compensated)	.035 (.015)	**
Comp3 (full compensation)	−.024 (.018)	
Children in household (Yes = base)		
No children	−.021 (.010)	**
N	1370	
Log likelihood	−713.946	

NOTE: The standard errors are shown in brackets. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively (two-sided *t*-test).

measures only the extra costs of the charge were presented to the respondent (it was not possible to present a realistic estimation of the benefits of lower income taxes). The purpose of the trips affects the level of effectiveness. The findings presented in the previous section on pricing effectiveness are here confirmed in terms of marginal effects, in the sense that commuting trips changed less strongly than "other" and "visiting" trips.

A dummy for working respondents is included. Working respondents do not appear to respond differently from nonworking respondents. Within the group of employed people driving from home to work, it does make a difference whether one has the opportunity to work at home on certain days. This group is more flexible and hence tends to change behavior sooner than others not having this possibility. Respondents driving to work (at least once a week) who obtain a partial compensation for their costs tend to change behavior sooner than other drivers. This result may have been anticipated for the first group, assuming that employers will also refuse compensation in the new situation. One explanation might be that compensation is in many cases rather modest or those respondents fear that the employer will not compensate costs in the new situation.

Respondents in the highest income category tend to be less price sensitive, and this is also what is found here. People without children are also less inclined to change behavior. Other types of trips (among which is bringing children to school) are more often changed, which may be one of the reasons. Other variables, such as age, car usage (yearly number of kilometers), frequency of facing congestion, gender (not included), or education (not included and correlated with income) do not appear to have an important impact on the level of self-reported effectiveness.

Measure 2. Peak–Off-Peak Kilometer Charge with Different Revenue Use

The second measure analyzed consists of a kilometer charge with an additional coarse peak charge during peak hours. The alternatives differ in charge levels and type of revenue use. In the section on pricing effectiveness, it was concluded that the impact of the type of measure on the level of effectiveness was not entirely clear. The outcomes in Table 6 confirm this pattern. The level of the charge is significant only for the difference between a peak charge of 12 and 24 (euro) cents, while the type of revenue use is not significant at all. The individual costs and the benefits, however, were presented differently to the respondents than with Measure 1. The difference is that here the level of the charge depends on the time of driving. And since information was not available on the number of kilometers driven during these peak periods, it was decided to present both extremes to each respondent (costs when all or no kilometers are driven during peak hours). While the off-peak charges are lower than with Measure 1, the peak charges are considerably higher. The benefits from lower car taxation may be perceived by the respondents as being rather low, which may explain the relatively stronger effectiveness levels for this measure for the first three alternatives. This then may also be an explanation for the insignificance of revenue use here.

In contrast with the previous measure, being employed makes a difference. Employed respondents (not necessarily making a commuting trip by car) appear to be less tempted to change behavior in general (for all types of trips). Another new factor is the importance of the number of times during a week that people usually face congestion. This measure leads to more trip adjustments among car drivers who regularly drive in congestion. The structure of the measure, mainly affecting peak hour drivers (when congestion is usually most severe), is the most likely reason for this. Similar to the previous measure, there is a significant impact (with the expected sign) of having the possibility of working home. This measure has no differentiated effect on trips made for a certain purpose. This finding corresponds with the results presented in Table 5, in which effect sizes for the purposes are comparable. Respondents with a higher income are less price sensitive, which is rather plausible. Finally, it appears that the compensation of costs by employers is important for the self-reported effectiveness of this measure, as with the previous measure.

CONCLUDING REMARKS

This paper presented the results from a stated-preference survey among Dutch car owners on behavioral responses to road pricing. For trips, the effectiveness of the measures is in the range of 6% to 15% for all purposes. It is often difficult to compare these results with previous literature because of differences in the measures analyzed and the research methods applied (modeling versus stated preference). The work discussed here probably comes closest to the research by MuConsult (*6*), although that study also included respondents who did not own a car. The outcomes in terms of kilometers for Measure 1A and 1B may be comparable to the results of the

TABLE 6 Estimation Results (Marginal Effects) of Tobit Analysis with the Effectiveness of Measure 2 as Dependent Variable

Variable	Tobit *y* Measure 2	Sign.
Constant	−.035 (.045)	
Yearly driven number of kilometers	−.634E-06 (.47E-06)	
Age	−.884E-03 (.67E-03)	**
Weekly number of times in congestion	.652E-02 (.26E-02)	***
Income (dummy inc1 = base)		
Incunk (income unknown)	−.200 (.069)	***
Inc2 (€28.500–45.000)	−.061 (.021)	
Inc3 (€45.000–68.000)	−.017 (.021)	**
Inc4 (>€68.000)	−.056 (.026)	
Type of measure (dummy charge 24 = base)		
Dummy peak charge 6 € cent	−.024 (.018)	**
Dummy peak charge 12 € cent	−.039 (.018)	
Type of measure (dummy road taxes = base)		
Dummy income taxes	.019 (.015)	
Trip purpose (dummy other = base)		
Dummy commuting	.021 (.019)	
Dummy visiting	.027 (.018)	
Employed		
Dummy yes	−.108 (.032)	***
Possibility to work at home (dummy working home2 and working home3 = base)		
Working home1 (possible)	.058 (.018)	***
Compensation for commuting costs (dummy comp4 and comp5 = base)		
Comp1 (no costs paid by employer)	.040 (.030)	**
Comp2 (costs partly compensated)	.058 (.024)	
Comp3 (full compensation)	.021 (.027)	
Children in household (Yes = base)		
No children	.163E-02 (.015)	
N	1370	
Log likelihood	−907.408	

NOTE: The standard errors are shown in brackets. **, and *** denote significance at the 5% and 1% level, respectively (two-sided *t*-test).

MuConsult study. The results then show stronger effects, which cannot be explained entirely by the fact that non-car owners were not included. The effect in terms of kilometers is somewhat smaller; probably people driving relatively less adjust their behavior.

A flat kilometer charge (Measure 1) may not have much effect on commuting trips. When policy makers want to affect these types of trips, they should consider a measure that is time differentiated, with higher charges during peak hours (as in Measure 2). Nonmotorized travel is a popular alternative for trips to visit people or shopping trips, especially when it concerns a flat kilometer charge. This suggests that people often take the car for short trips that can be most easily replaced by walking or cycling. However, this sample includes relatively few elderly for whom walking or cycling may not always be an option. Driving at other times is also popular, especially for the car-dependent commuting trips. Commuting trips are hard to reduce (working at home or not making the trip are not serious options for most of the respondents), but there appears to be some level of flexibility allowing scheduling of trips.

The impact of the type of measure is not straightforward. Previous research and common sense suggest that higher kilometer charges should have more impact. The results are somewhat mixed on this issue and are difficult to explain. The effect of revenue use appears clear from the analysis: revenues allocated to lower-income taxes generally have more effect (but not significantly different for the peak–off-peak measure). This may be explained partly by the "perceived" income effect, as it is caused by the design of the questionnaire. An estimate of the benefit from recycling could be calculated and shown to the respondent for car tax reductions but not for income tax reductions.

The statistical analysis showed that charge level has a significant impact for the flat charge, while only the difference between the high and middle charge level is significant for the peak time measure. For both measures, the possibility of working at home is an important explanatory variable. People who have more flexibility tend to change trips more frequently. Employed respondents appear relatively unwilling to change trips. Higher-income people appear to be less price sensitive, which appears rather plausible. Other characteristics, such as age and the number of kilometers driven yearly, tend to have a minor effect on the level of effectiveness.

Finally, it is hard to determine whether or not these results can be generalized to other countries. For example, the availability (transit) and inherent popularity (cycling) of alternatives may differ between countries; the spatial structure may be different, and many other factors may cause further deviations. Although it is tempting to present, for example, the conclusion on the importance of time differentiation of charges for effectiveness in commuting as a more general result, such conclusions cannot be drawn from this study and therefore are left as material for further (local) study.

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REFERENCES

1. Victoria Transport Policy Institute, Victoria, British Columbia, Canada. *Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior.* Online TDM Encyclopaedia at www.vtpi.org/tdm/tdm 11.htm#_Toc18128471. Accessed July 15, 2005.
2. Oum, T. H., W. G. Waters II, and J. S. Yong. Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates, an Interpretative Survey. In *Transport Economics* (T. H. Oum, J. S. Dodgson, D. A. Hensher, S. A. Morrison, C. A. Nash, K. A. Small, and W. G. Waters II, eds.), Harwood Academic Publishers, Amsterdam, Netherlands, 1997, pp. 17–49.
3. Goodwin, P. B. Review of New Demand Elasticities with Special Reference to Short and Long Run Effects of Price Changes. *Journal of Transport Economics and Policy,* Vol. 26, No. 2, 1992, pp. 155–171.
4. Olszewski, P., and L. Xie. Modeling the Effects of Road Pricing on Traffic in Singapore. *Transportation Research Part A,* Vol. 39, 2005, pp. 755–772.
5. MuConsult. *Variabilisatie van de autokosten.* Final report. Amersfoort, Netherlands, 1998.
6. MuConsult. *Onderzoek naar de Effecten van Kilometerheffing.* concept Onderzoeksrapport. Amersfoort, Netherlands, 2002.
7. Adviesdienst Verkeer en Vervoer. *Verkeerskundige effecten varianten 'Anders Betalen voor Mobiliteit.'* Rotterdam, Netherlands, 2005.
8. Tobin, J. Estimation of Relationships for Limited Dependent Variables. *Econometrica,* Vol. 26, 1958, pp. 24–36.
9. Maddala, G. S. *Limited-Dependent and Qualitative Variables in Econometrics.* Cambridge University Press, New York, 1983.

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